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STUDY OF MECHANICAL AND ABRASIVE WEAR PROPERTIES OF LANTANA CAMARA PARTICULATE REINFORCED EPOXY COMPOSITE

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Abstract

Natural fibres have gained researchers' attention as a replacement to synthetic materials for reinforcing material in polymers such as epoxy due to their advantages such as environment friendliness, biodegradability, renewability and cost effectiveness. Due to such advantages, further exploration of new natural fibres as a filler material in polymer matrix composites for different tribological applications is needed. Lantana camara is one such abundant natural resources whose potential as filler material in polymer composite has not been explored to such a level till date. The present experimental study aims at studying abrasive wear behaviour of lantana camara powder reinforced epoxy composites and their mechanical properties such as tensile and flexural strength. Composites having 10, 20 and 30 weight percentage of lantana camara powder were fabricated using hand layup technique to study the tensile, flexural, impact strength properties along with abrasive wear behaviour on a pin on disc wear tester. It was found that both the abrasive wear resistance and strength of the composite samples can be significantly improved by the incorporation of lantana camara particulates into epoxy. At 20 weight. fraction of lantana camara both the wear resistance and strength of the composite were found to be optimum. However, further addition of particulate (30%,40%) results in increase of wear rate as well as lowering of strength. SEM studies were conducted for the wear out samples to study the failure nature at the microscopic level.
Keywords: Natural fiber, lantana camara, polymer composite, abrasive wear, mechanical properties, tribology; **1.**

Introduction

The need of the hour has demanded the exploration of fresh options in natural fiber reinforcements for polymer composites [1]. The natural fiber composites can be used in various applications ranging from household apparatuses to high end products such as aerospace applications [2]. They can be also used for automobiles and in various structural applications [3]. The wide range applications of these composites has attracted researchers for the continual upgradation of their properties [4].

Wear is the undesirable removal of material when two contacting surfaces have relative motion [5]. Wear is one of the feature of the tribology which depends on various factors such as load, speed, temperature and environmental

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condition [6]. The wear behavior of natural composites vary with different filler material and detailed analysis of it forms a crucial task to be performed before the application of such composite in different applications. To understand the wear mechanism in different sliding conditions wear map have been used [7]. Abrasive wear is a kind of wear which is experienced when a hard surface slides over a soft surface and removes abrasive grooves from the less hard surface [8]. Material failure due to abrasive wear is one of the most common types of failure mechanisms in day to day practice and also in industrial application of natural composites [9].

Lantana camara is a perineal shrub which can be grown in a variety of environments [10]. It is locally known as 'putus'. It is one such natural resource which has been underutilized for the role of reinforcement in polymer composites till time. Limited works have been carried out on the tribological behavior of short lantana camara fiber. But till time, researchers have not used lantana camara in particulate form to study the behaviour of reinforced composite for tribological applications along with mechanical characteristics. This work is aimed at the above mentioned research gap to study the effect of incorporation of lantana camara in epoxy based polymer composite.

2. Experimental Details

2.1. Materials

Lantana camara stem were collected from the local vendors. The stems were sun dried for 24 hours to remove the moisture. The outer skin (Figure 1(a)) was separated from the stem and bare skinned stems were cut into small pieces. The small pieces were oven dried at 60^0c for 6 hours to remove moisture. These small pieces again converted in to powder for with help of grinding and ball milling. The fine powder (Figure 1(b)) obtained was further separated using sieve shaker. In this work Araldite LY556 was used as the epoxy resin with HY951 as the hardener with epoxy with a ratio of 10:1.

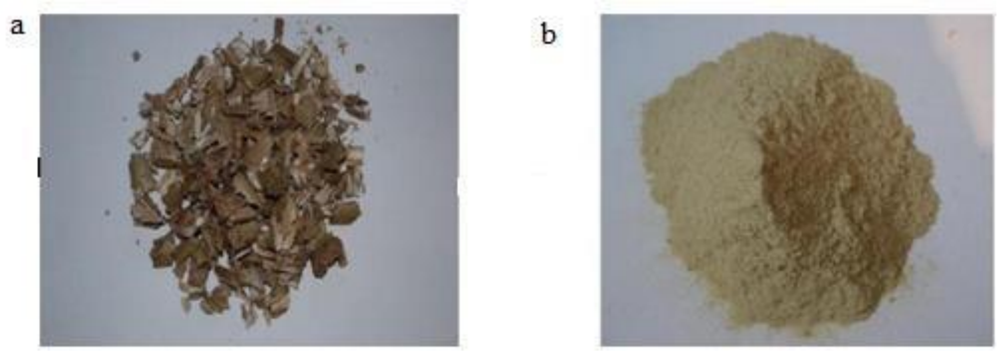

Fig. 1. (a) Outer skin of Lantana camara stem; (b) Lanatana camara particulate.

2.2. Composite fabrication for tensile and flexural test specimens

The composite samples were fabricated using a wooden mold by usual hand lay-up technique. At first, the weights of powder and epoxy were calculated with the help of a weighing machine for different volume fraction of lantana camara powder. Then a mixture of calculated epoxy resin and hardener (ratio of 10:1 by weight) was formed by gentle stirring followed by mixing of lantana camara powder. After proper mixing of powder and epoxy, the mixture was poured carefully into the mould. A mould release spray was applied throughout the inner surface of the mould before pouring so that the removal of composites was fast and easy. The mould was pressurized from the top by some weights and left for curing at room temperature for 24 hours. Care was taken to consider the loss of materials when they squeezed out of the mould due to application of pressure. This procedure was adopted for fabrication of composites which consists of 10, 20,30 and 40% weight fractions of Lantana camara.

2.3. Tensile test

The samples were cut into the dog bone shape according ASTM D 3039-76 standard [11] on a universal testing machine. The test was conducted with span length 40mm and strain rate 2mm/min. Five samples were tested and average value of the results were considered. The modulus of elasticity of the specimens were found to be increasing order until 20% of the reinforced filler followed by the gradual decrease of tensile strength.

2.4. Flexural test

Three-point bend test of the specimen was conducted using the same instrument as that of tensile strength test. All the specimens were of rectangular shape with dimension 140*20*5 mm^3.The test was conducted with a span length of 100mm and a cross-head speed of 0.5 mm/min [12].

2.5. Impact strength test

The impact test was conducted with izod impact tester and ASTM D 256 standard was followed [13]. The dimension 63.5*12.7*5 mm3 and a 'V' notch was made at the Centre of specimen with depth of 5 mm and 45° notch angle.

2.6. Composite fabrication for wear test specimens

The composite samples were fabricated using a steel mould by usual hand lay-up technique [14]. At first, the weights of powder and epoxy were calculated with the help of a weighing machine for different volume fraction of lantana camara powder. Then a mixture of calculated epoxy resin and hardener (ratio of 10:1 by weight) was formed by gentle stirring followed by mixing of lantana camara powder. After proper mixing of powder and epoxy, the mixture was poured carefully into the mould. A mould release spray was applied throughout the inside surface of the mould before pouring that the removal of composites was fast and easy. The mould was pressurized from the top by some weights and left for curing at room temperature for 24 hours. Care should be taken to consider the loss of materials when they squeezed out of the mould due to application of pressure. This procedure was adopted for fabrication of composites which consists of 10,20 and 30 wt. fractions of lantana camara.

2.7. Dry sliding wear test

Abrasive wear test was conducted on a pin-on-disc machine as per ASTM G-99 standard [15]. A circular disc was glued by an abrasive paper of 320 grade (grit-36 µm. A sample holder was used to hold the specimens which will undergo for testing. At a track radius of 50mm which remains constant for the whole experiment the holder along with the specimen was located. The process was reiterated for a total time of 25 minutes which consists of 5 sets each of 5 minutes. The specimen was pressed against the disc by a dead weight loading system. The rotational speed (rpm), external load in the load panel were varied with different samples. Before and after each tes , the weight of specimens were recorded and the change in weight in the process was noted for further analysis. Then the specimens were stored for microstructure analysis of worn surface.

Table 1. Experimental parameters of abrasive wear test

Experimental parameters	Units	Values
Weight percentage of filler	%	0,10,20,30
Load(L)	N	5,10,15,20
Sliding Velocity(v)	m/s	1.0471,1.5709,2.094
Track radius	m	0.05
Temperature	0^0C	25

2.8. Calculation of wear

Wear is determined by calculating the change in weight of the specimens after each testing. The Change in weight was calculated using equation 1:

$$\Delta m = (m_1 - m_2)\ g \ldots\ldots\ldots\ldots (1)$$

where Δm stands for the change in weight of the specimen and m_1 and m_2 represent the initial and final weight of a specimen for a test.

The abrasive wear rate (W) can be determined by using the following equation:

$$W = \Delta m/SD \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where SD stands for sliding distance in meter

The Volumetric wear rate (Wv) can be calculated by the following equation

$$Wv=\Delta m/\rho * SD \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The specific wear rate can be calculated by using following equation:

$$Ws=\Delta m/\rho * SD * F \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where, m stands for the mass loss in, SD stands for sliding distance and F stands for the normal load applied.

3. Results and Discussion

The measured mechanical properties of composites with different weight fraction of filler are tabulated in Table 1. It is evident that mechanical strength and modulus of the composite increases with addition of lantana camara particulate. The 20 weight percent lantana camara epoxy composites gives optimum mechanical characteristics. However, excessive addition of particulate (30% and 40%) results in increase in void content in the composite resulting in lowering of strength.

Table 2 Mechanical test results of lantana camara reinforced epoxy composite

Weight fraction of filler (%)	Tensile strength (MPa)	Tensile modulus (MPa)	Flexural strength (MPa)	Flexural modulus (GPa)	Impact Strength (Joules/cm^2)
0	20.64	1303	33.97	2.854	1.96
10	22.18	1466	41.16	2.988	3.26
20	26.31	1738	53.4	3.924	5.3
30	20.30	1341	39.5	3.804	4.47
40	19.18	1029	28.8	2.961	3.96

The wear behavior of the specimens varied with different sliding distances for different loading conditions (5, 10,15 and 20N) and different sliding velocities of 1.0472, 1.5708 and 2.0944 m/s. It is evident from graphs that with addition of lantana camara powder the wear properties of composite has improved. It was observed that when sliding distance for all the composite samples increases, the wear rate decreases (fig. 2.(a)). Further it has been noticed that, in all cases the range of wear loss is in higher side at the beginning stage of sliding distance and become steady after some time. In other words, at longer sliding distances there is less removal of material since penetration of abrasive particle into the composite sample decrease due to reduced depth of penetration of particles since abrasive paper become smooth due to wear debris fill up the space between abrasives. For the present case, the minimum wear loss is obtained at 20 weight percent lantana camara particulate reinforced composite under all testing conditions.

The specific wear rate variation for different weight fraction of particulate (10, 20 and 30%) composites with sliding velocity at varying applied loads (5, 10,15 and 20N) were studied (fig.2. (b)). It is evident from the graphs that with the increase of loading conditions from 5N to 20N the specific wear rate increases linearly with sliding velocity.

The volumetric wear rate variation with normal loads for different wt. fraction of particulate composites at different sliding velocities are shown in fig.3. (a). It is evident from the graphs that with the raising of normal loads, volumetric wear rate increases. At smaller normal load wear rate is relatively low due to lower penetration which is due to less number of abrasive particles penetrate into the sliding surfaces. However, at higher loads wear rate is increased in large scale due to large participation of the abrasive particles which creates more grooves.

The variation of specific wear rate with different wt. fractions of filler are shown in Figure fig.3 (b). It is evident from the plotting of graphs, that, the specific wear rate becomes less with increasing weight fraction of particulate irrelevant of sliding velocity. However, excessive addition of particulate (30%) results in increase of specific wear rate since void content increases due to detachment of particulates from the matrix.

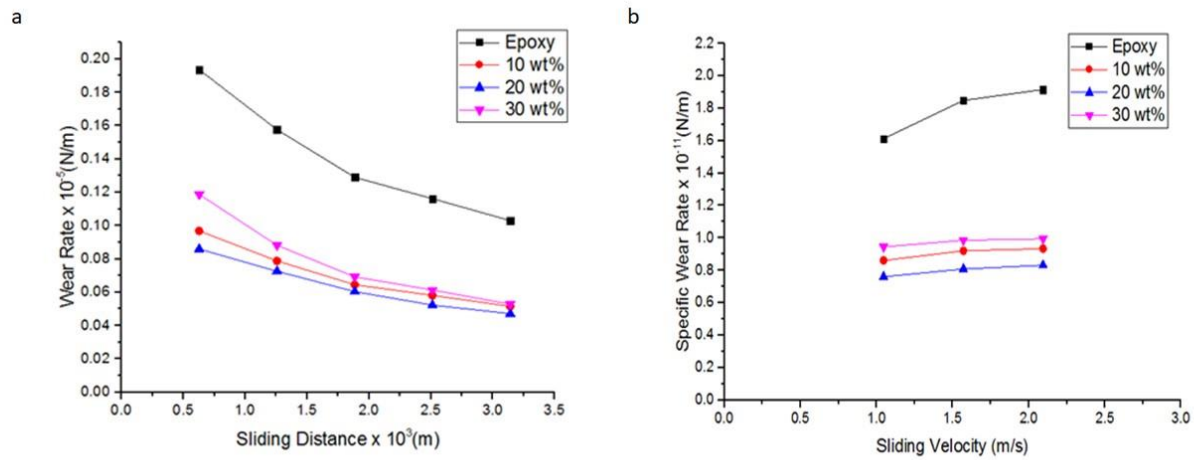

Fig. 2. (a) Variation of abrasive wear rate w.r.t. sliding distance; (b) Variation of specific abrasive wear rate w.r.t. sliding velocity.

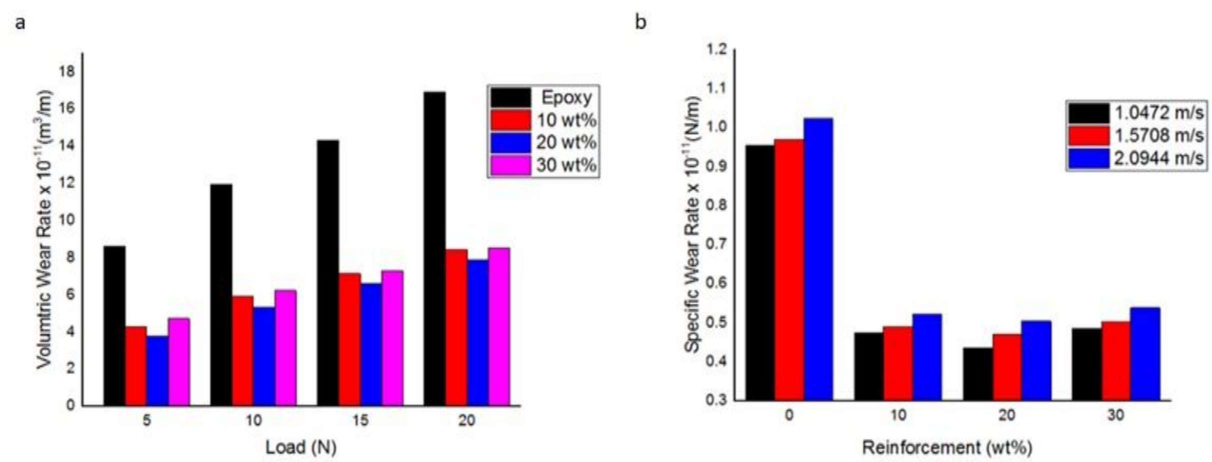

Fig. 3. (a) Variation of volumetric wear rate w.r.t. different loads; (b) Variation of specific abrasive wear rate w.r.t. different filler percentage.

3.1. Microstructure Analysis

For the identification of the abrasive wear behavior of the composite, the abraded surface of the specimens was tested under SEM. The specimens were first coated with platinum in a vacuum environment with the help of a coating device to increase their conductivity before taking the photographs. Micro cracks were found on the abraded surface of the specimens. The abraded surface of particulate reinforced composite are shown fig.3(a,b).From the figure3(b) the detachment of particulates from the matrix was clearly seen on the abraded surface . Micro crack propagation originating due to micro-groove formation and poor fiber matrix adhesion in the wear surface led to lowering of wear resistance and caused the surface breakage.

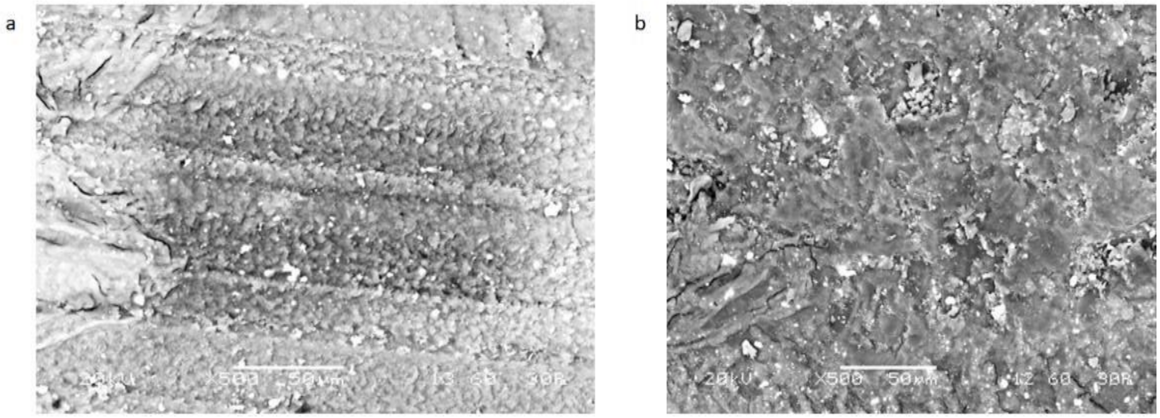

Fig. 4. (a) Abraded surface of the specimen; (b) Micro cracks originated in the specimens.

4. Conclusion

- The lantana camara particulate can efficiently be utilized as a filler in the polymer composite for the improvement of the quality of products using suitable resin.
- The abrasive wear loss can be significantly reduced by the incorporation of lantana camara into epoxy. The optimal wear resistance was found for the composite specimens with filler of 20 weight percentage of lantana camara. However, further addition of particulate (30%) results in increase in void content in the composite resulting in increase of wear loss.
- As the sliding distance increases, wear rate gradually decreases and becomes steady after some time in multi-pass condition.
- Abrasive wear increases marginally with increasing sliding velocity where as it increases rapidly with increase in normal load. Thus it can be concluded that abrasive wear rate is more sensitive to normal load than the sliding velocity.
- The tensile and flexural strength of the composite increases with addition of lantana camara particulate. The 20 wt. percent lantana camara particulate reinforced epoxy composites gives optimum tensile and flexural strength. However, excessive addition of particulate (30% and 40%) results in increase in void content in the composite resulting in decrease of strength.

5. References

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